National Aeronautics and Space Administration

HEOMD NASA Advisory Council Public Session

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What Were HEO's Biggest Accomplishments In 2013?

- Safe and successful operation of the ISS;
- ISS utilization: increase crew hours, benefits to humanity, new capabilities like rodent research on SpaceX 4
- Successful accomplishment of the Commercial Cargo Program, resulting in two providers of ISS cargo transportation services
- Received and evaluated the initial Certification Products Contracts Phase I products
- Successful accomplishment of the CCiCAP partners' milestones
- SLS preliminary design review
- Installation of SLS manufacturing tooling at Michoud Assembly Facility
- Delivery of Orion heatshield
- Orion power on
- Successful launches of TDRS-L, Landsat 8, and MaVEN
- Successful Lunar Laser Comm Demonstration from LADEE spacecraft in lunar orbit
- Initial definition of the Asteroid Redirect Mission

What Are HEO's Biggest Challenges In 2014?

- Extending ISS beyond 2020 enables the nation's goals in space – commercialization, extending humans beyond low Earth orbit, returning benefits & humanity, and leading a global exploration partnership
- Continue safe, innovative and productive use of ISS, including achieving a regular cadence of commercial cargo flights. Most important thing is to use this unique facility to expose others to the benefits of space based research
- Receive, evaluate, and select CCtCAP provider(s)
- Deliver the Orion test article and fly EFT-1
- Guide SLS through Agency approval for final design and fabrication, and continue hardware development as the overall design matures to critical design review
- Establish the pathway for SLS upper stage development including international partner roles
- Keep Orion and the ESA service module on track
- Take ARM Mission into formulation
- Launch TDRS-L successfully and implement Space Network Ground Segment Sustainment


Asteroid Redirect Mission and
The Future of Human Spaceflight

Leveraging Capabilities for an Asteroid Mission

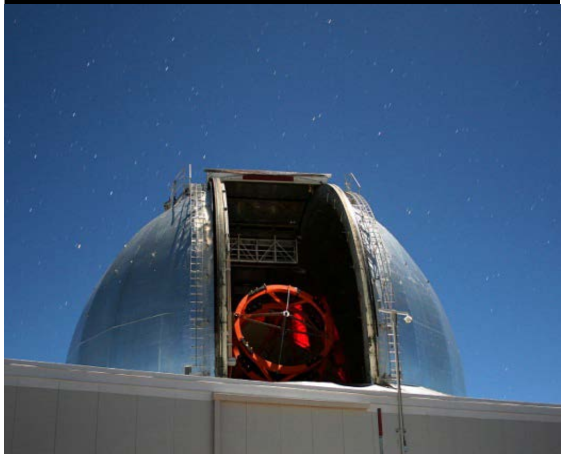
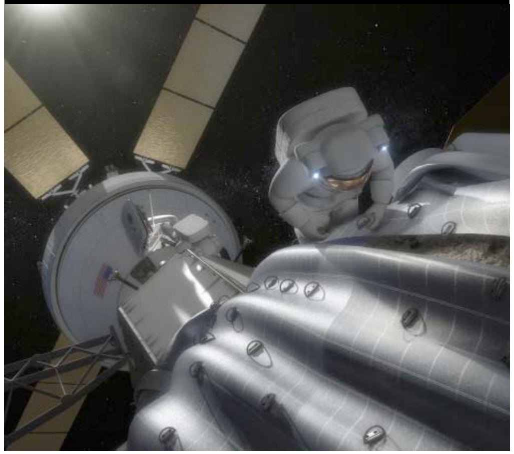
- **NASA is leveraging key on-going activities in Science, Space Technology, and Human Exploration and Operations Mission Directorates**
  - Asteroid identification and characterization efforts
  - High power solar electric propulsion
  - Autonomous guidance and control
  - Orion and Space Launch System vehicles
  - Technologies for astronaut extra-vehicular activities

- **Each individual activity provides an important capability in its own right for human and robotic exploration**

- **We are working to utilize all of these activities to**
  - Identify and redirect a small asteroid to a stable orbit in the lunar vicinity; and
  - Investigate and return samples with our astronauts.

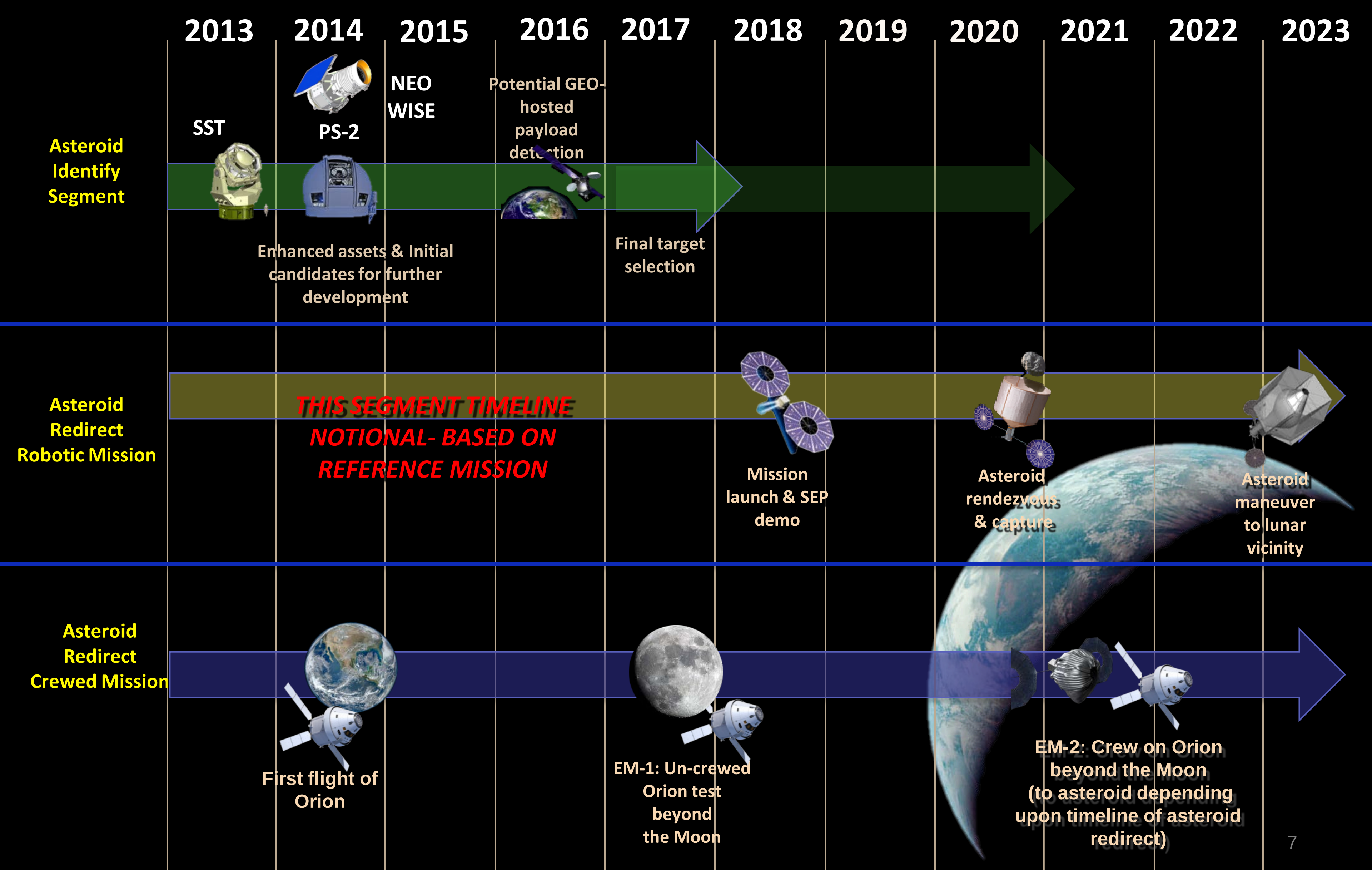
- **The FY14 budget supports continued advancement of the important individual elements and furthers the definition of the overall potential mission.**

Asteroid Redirect Mission

Identify	Redirect	Explore
		
Asteroid Identification: Ground and space based near Earth asteroid (NEA) target detection, characterization and selection	**Asteroid Redirect Robotic Mission:** High power solar electric propulsion (SEP) based robotic asteroid redirect to lunar distant retrograde orbit	**Asteroid Redirect Crewed Mission:** Orion and Space Launch System based crewed rendezvous and sampling mission to the relocated asteroid

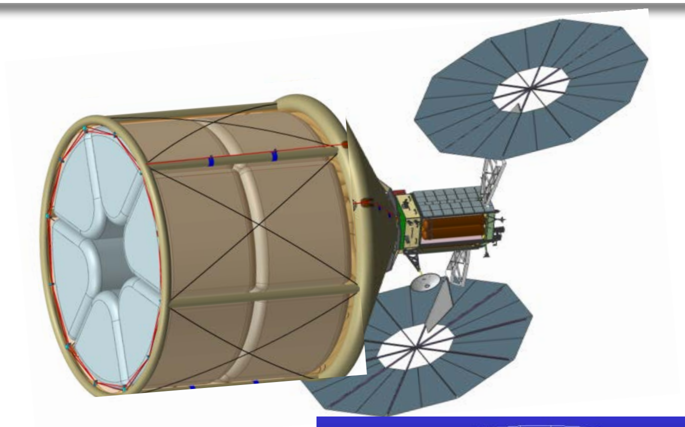
Leveraging On-Going Activities
Each Provides Important Individual Capability

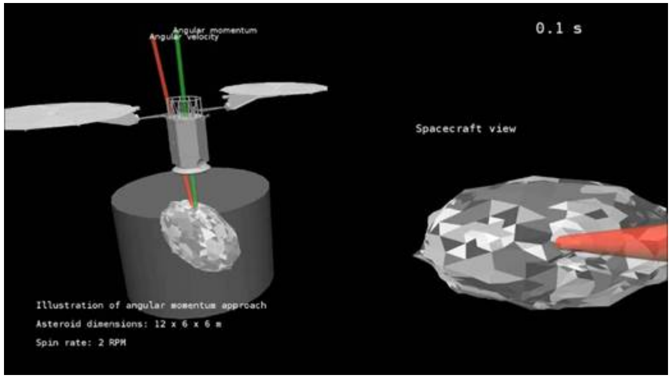
Alignment Strategy for a Mission



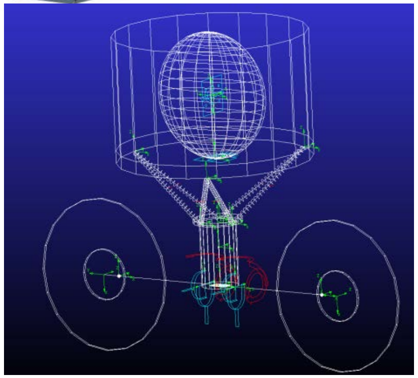
Capture Mechanism Placeholder

- Capture bag designed to capture worst case rubble pile, using inflatable exoskeleton forming a cylindrical barrel section and conical section, actual size will depend on target





- Performing various dynamic analyses to assure robust system for capture at slow and fast rotation states while limiting forces on S/C

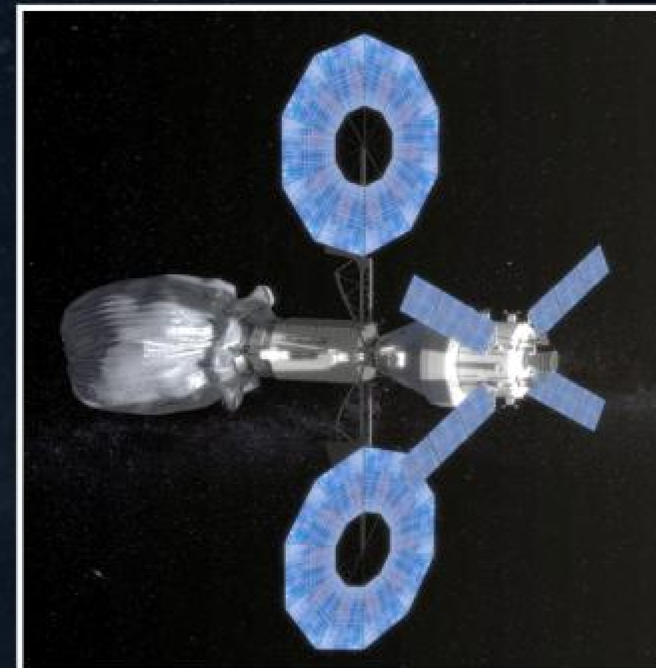


- Built 1/5 scale testbed
  - To help characterize stiffness and damping, forces on the bag, and general control of the bag and fabric
  - Upgrades to system to include pie-shaped inner bags for fast rotation capture planned for spring 2014.

Asteroid Redirect Crewed Mission Overview

Deliver crew on SLS/Orion

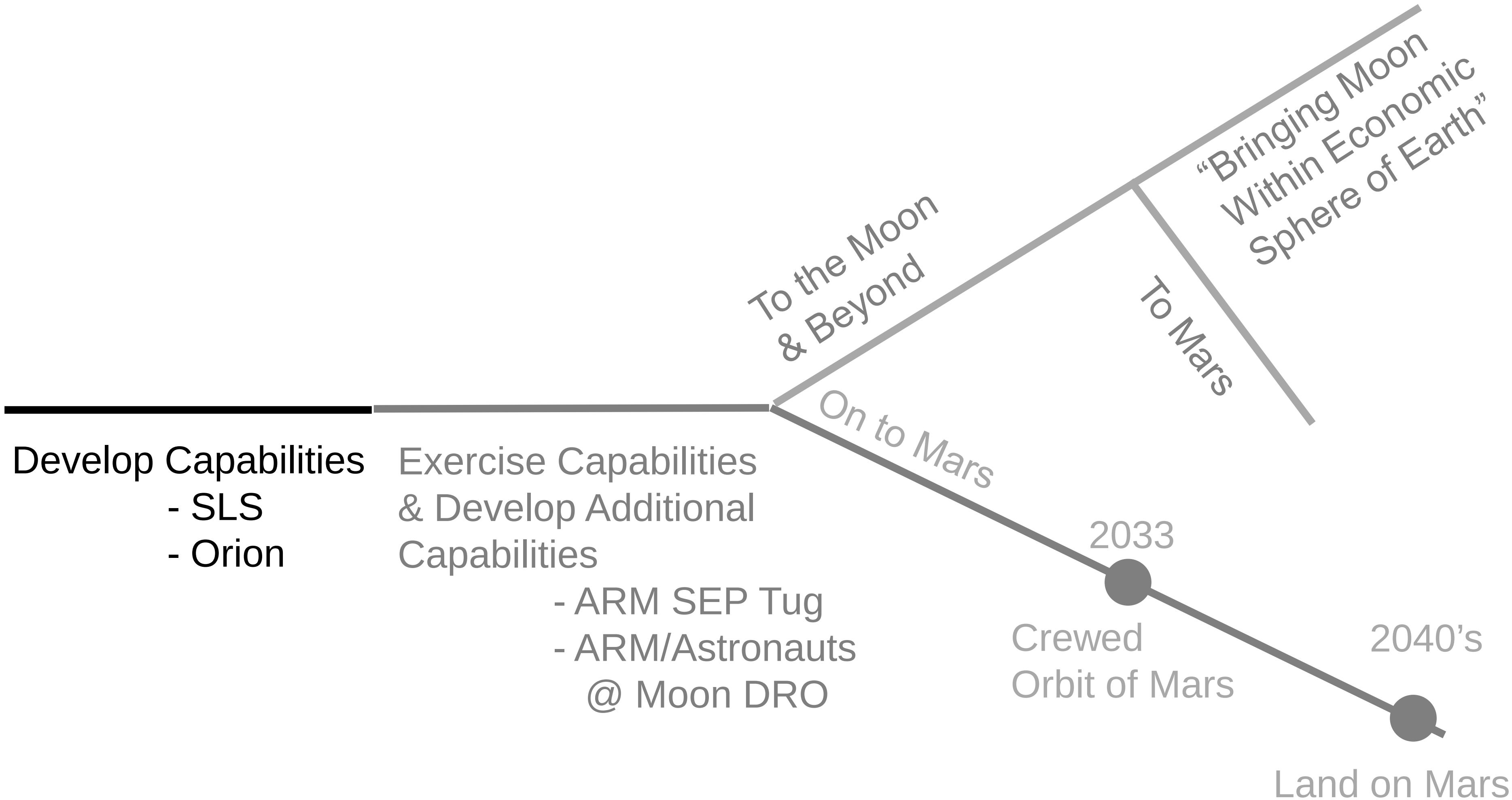
Attached Orion to robotic spacecraft



Perform extra-vehicular activity (EVA) to retrieve asteroid samples

Return crew safely to Earth with asteroid samples in Orion

Example Human Exploration Pathways



FY13 Modified ACES Testing Progress

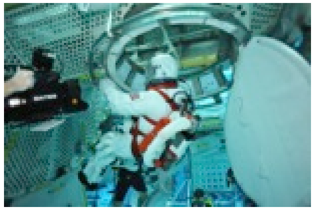
Winter 2012

MACES EVAs are demonstrated as feasible and neutrally buoyant testing is warranted

June 28th – Test #3 (2hr)

Improvements in suit fit procedures needed

July 22nd – Test #5 (2hr)



Great capability improvements observed in subsequent runs indicating that training on the suit is vital.

Sept. 25th – Test #8 (4hr)

Best demonstration of suit capabil ity, attributed to good suit fit that allowed the subject easier access to standard work envelope.

May | June | July | August | September

May 5th – Test #1 (2hr)

Established baseline weigh out and ECS interface (both to be improved)

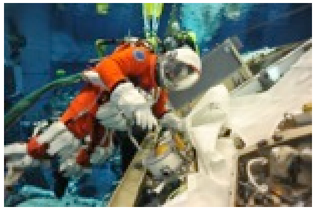
June 7th – Test #2 (2hr)

Established need for robust EVA gloves (EMU PhaseVI)

July 12th – Test #4 (2hr)

Two-handed task difficulties established need for suit shoulder biasing and better worksite stabilization

Sept. 6th – Test #6 (3hr)



Suit fit specific to EVA operations continues to be a significant performance factor

Sept. 16th – Test #7 (4hr)

Suit system demonstrated feasibility of 4 hour EVAs.

Hardware and Procedure Improvements

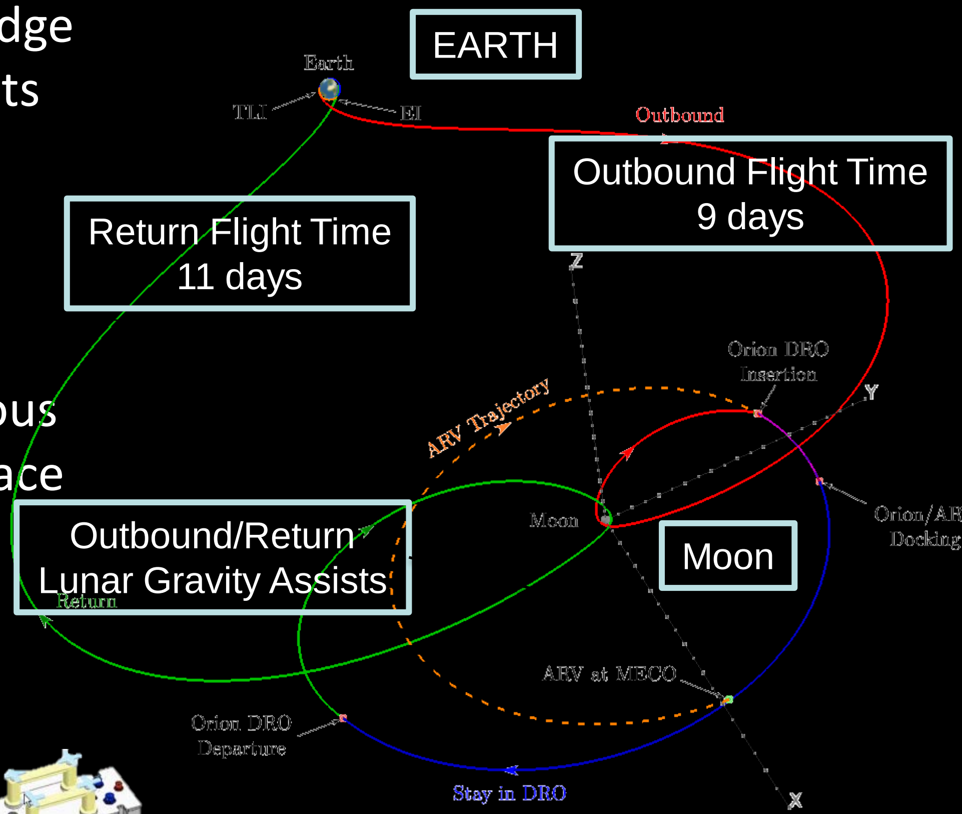
- Improved weights
- Phase IV Gloves
- Added tool harness
- Cooling System modifications
- Drink bag included
- Improved Poolside Procedure
- New liquid cooling garment

EVA Technique Development

Asteroid Mission NBL Testing

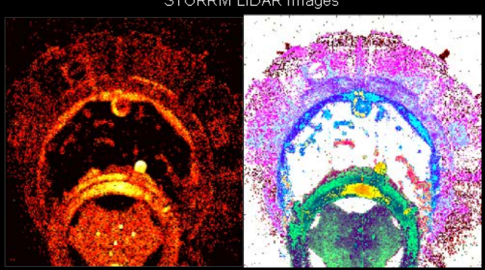
Leveraging Trajectory and Rendezvous

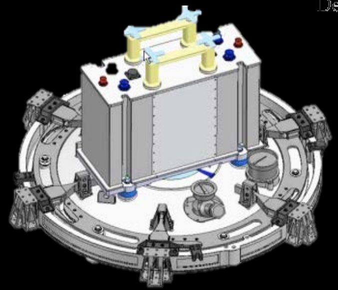
- Common sensors derived from knowledge gained from Space Shuttle Detailed Tests
- Synergy between crewed and robotic mission sensors
- Trajectory launch constraints, rendezvous techniques, navigation enable deep space



STORRM Camera Image

STORRM LIDAR Images





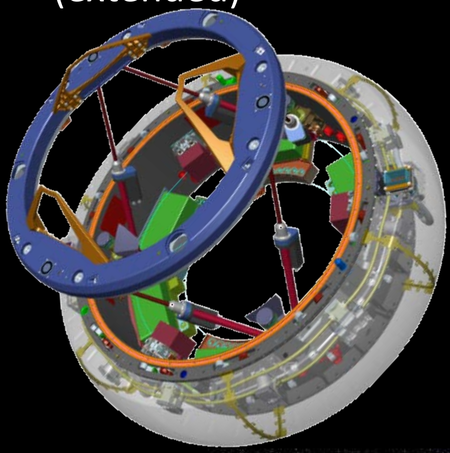
Notional Relative Navigation Sensor Kit

Outbound Flight Time: 8 days, 9 hrs
Return Flight Time: 11 days, 6 hrs
Rendezvous Time: 1 day
DRO Stay Time: 5 days

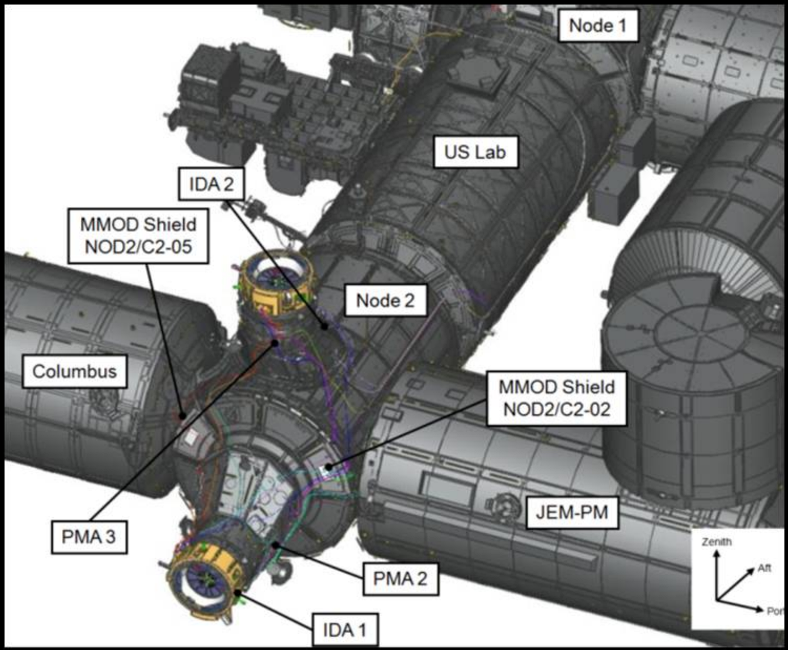
Docking System

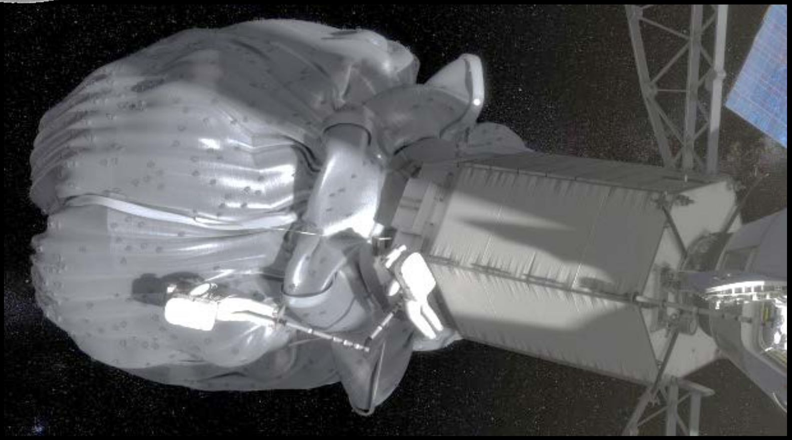
- **Docking System for Orion and Robotic Spacecraft leverages development of International Docking System Standard**

Orion Active Docking Mechanism (extended)



Robotic Spacecraft Passive Docking Mechanism



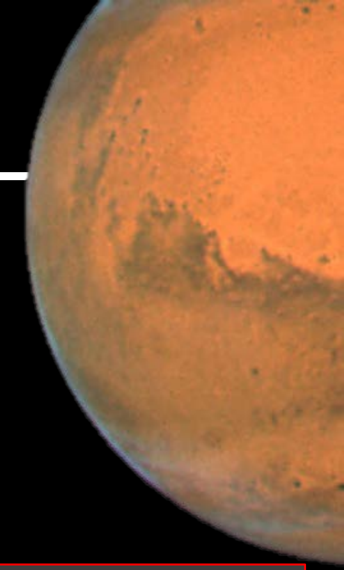


- International Docking Adapter will create a docking port on ISS
- Compatible with new International Standard
- Provides Power and data utility connections to visiting vehicles
- Delivered to ISS in trunk of Space – X Dragon Cargo Vehicle

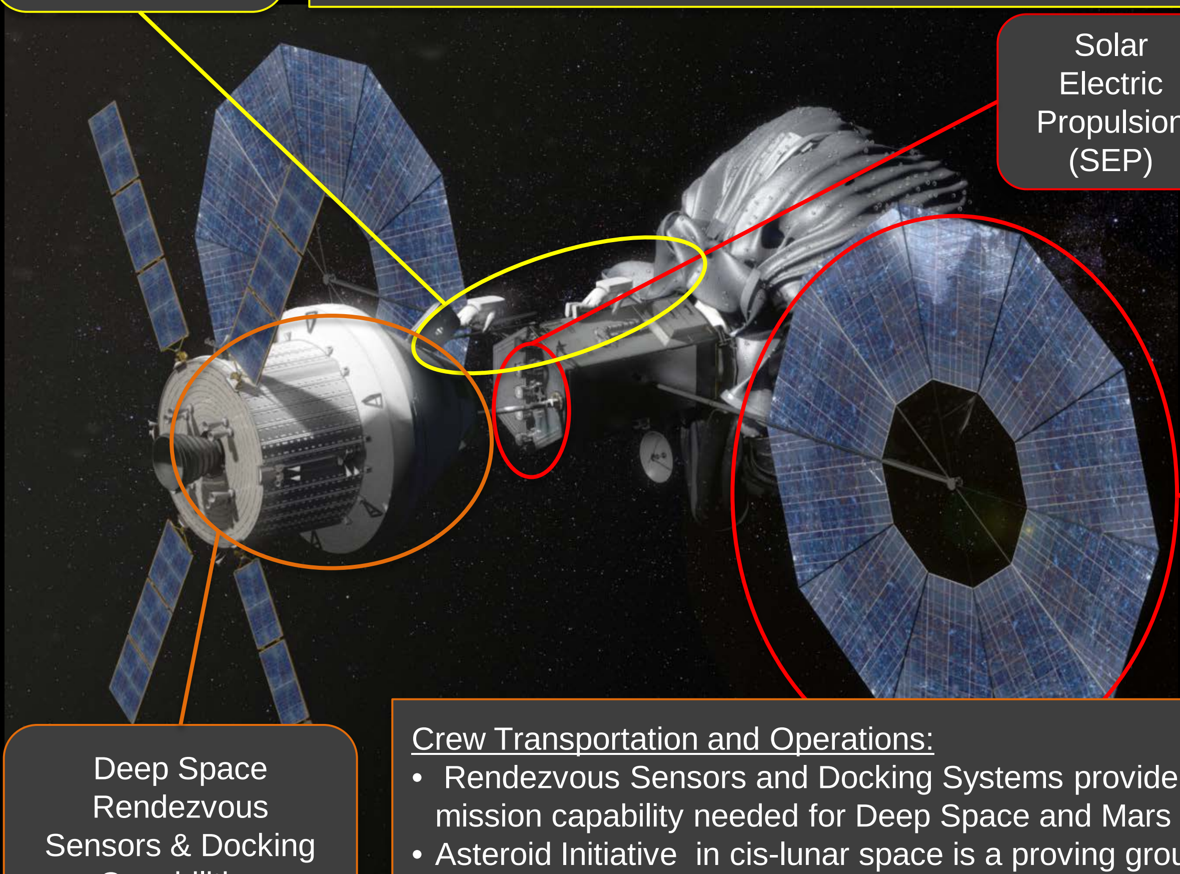
ARM Provides First Steps to Mars/Other Destinations

Sequence	Mission	Current ISS Mission	Asteroid Redirect Mission	Long Stay In Deep Space	Mars Orbit	Mars Surface, Short Stay	Mars Surface, Long Stay
Mars Destination Capabilities	In Situ Resource Utilization & Surface Power						X
	Surface Habitat						X
	Entry Descent Landing, Human Lander					X	X
	Advanced Cryogenic Upper Stage				X	X	X
Initial Exploration Capabilities	Solar Electric Propulsion for Cargo		X	X	X	X	X
	Exploration EVA		X	X	X	X	X
	Crew Operations beyond LEO (Orion)		X	X	X	X	X
	Deep Space Guidance Navigation and Control/Automated Rendezvous		X	X	X	X	X
	Crew Return from Beyond LEO – High Speed Entry (Orion)		X	X	X	X	X
	Heavy Lift Beyond LEO (SLS)		X	X	X	X	X
ISS Derived Capabilities	Deep Space Habitat	*	→	X	X	X	X
	High Reliability Life Support	*	→	X	X	X	X
	Autonomous Assembly	*	→	X	X	X	X

Asteroid Initiative Extensibility for future Deep Space/Mars Missions



EVA:
- EVA kits build capability for future exploration:
  - MACES
  - PLSS (Design accommodates Mars)
- Follow-on Asteroid Utilization mission can provide more capable micro-g exploration suit
- Technologies allow NASA to develop the next generation surface suit and PLSS.

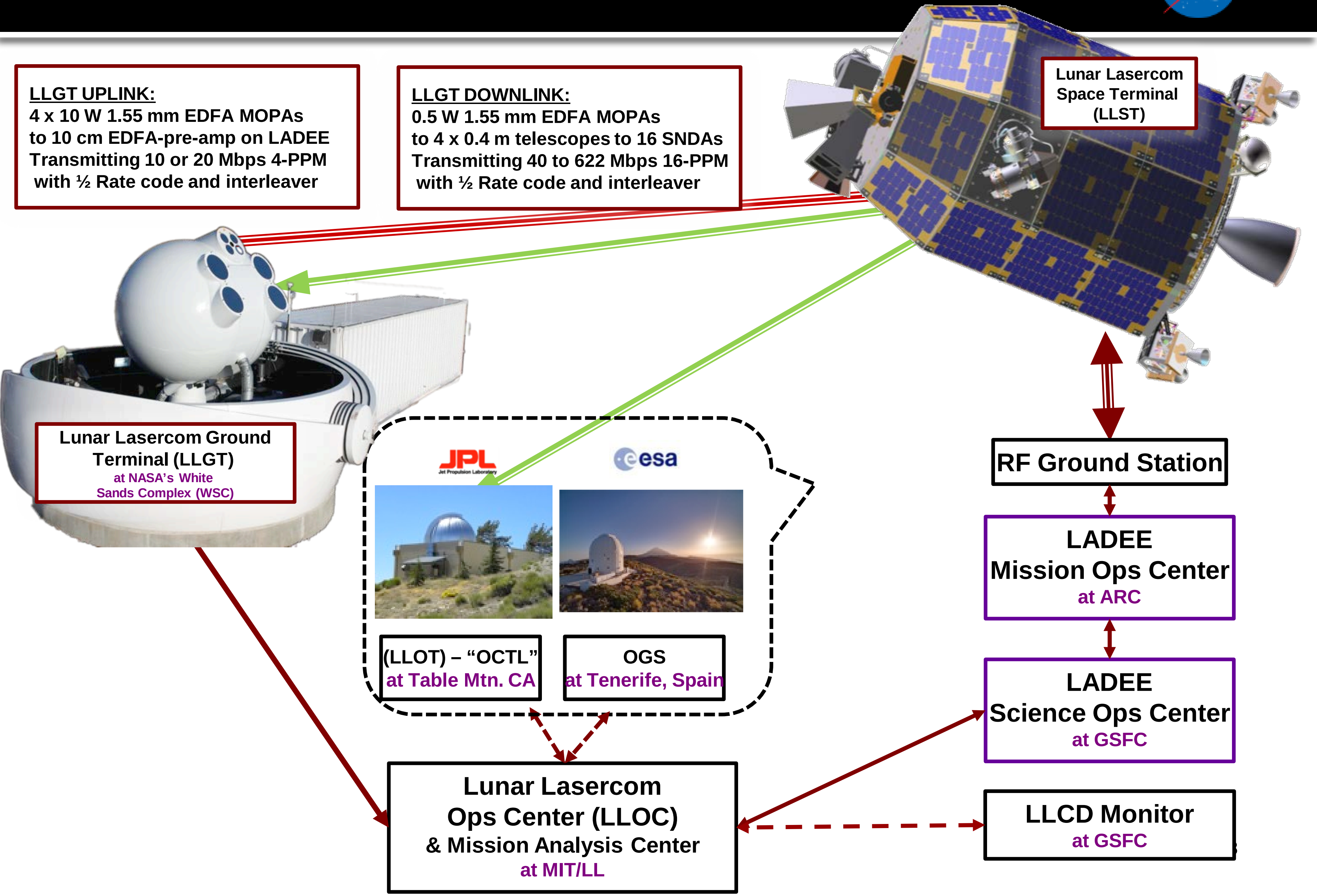


In-space Power and Propulsion :
- High Efficiency Solar Arrays and SEP advance state of art toward capability required for Mars
- Robotic ARM mission 50kW vehicle components prepare for Mars cargo delivery architectures
- Power enhancements feed forward to Deep Space Habitats and Transit Vehicles

Crew Transportation and Operations:
- Rendezvous Sensors and Docking Systems provide a multi-mission capability needed for Deep Space and Mars
- Asteroid Initiative in cis-lunar space is a proving ground for Deep Space operations, trajectory, and navigation.

Space Communications and Navigation Update

LLCD Mission Architecture



Project Accomplishments – LLST to the Lunar Lasercomm Ground Terminal (LLGT)

Performance to Date:

- ✓ Regular, instantaneous (seconds!) all-optical acquisition and tracking between LLST and LLGT
- ✓ Error-free D/L to LLGT at 40, 80, 155, 311 Mbps
- ✓ 622 Mbps D/L regularly achieved with a code word error rate (CER) < $1x10^{-5}$ (Req. < $1x10^{-4}$)
- ✓ Error-free U/L from LLGT at 10, 20 Mbps
- ✓ Initial TOF measurements collected and being processed to allow centimeter-class ranging
- ✓ Error-free operation at low Moon elevation angles (< 4 degrees at White Sands/LLGT!)
- ✓ Operation to within 3 degrees of the Sun at up to 622 Mbps with no degradation at the LLGT!

Operational Achievements to Date:

- ✓ LLST U/L commanding sent and LLST telemetry received over optical link
- ✓ LADEE spacecraft data downlinked through high-speed data interface to LLST Modem; entire 1 GB LADEE buffer downlinked in < 5 min @ 40 Mbps (LADEE C&DH limit)
- ✓ Multiple streaming HD videos transmitted to the Moon and looped back to LLGT at 20 Mbps (limited by U/L rate)
- ✓ All-optical (no RF!) Comm passes using automated scripts to awaken and point LLST on schedule

Project Accomplishments –
JPL OCTL and ESA OGS Ground Terminals

<u>JPL's LLOT Ground Terminal (OCTL)</u>

- ✓ Regular, instantaneous (seconds!) all-optical acquisition and tracking between LLST and OCTL
- ✓ Properly-framed, error-free D/L to JPL's OCTL at 40, 80 Mbps
- ✓ Operation at low elevation angles of the Moon (degrees at JPL's Table Mountain/LLOT)
- ✓ **"Hand-off" from WSC to JPL during pass in < 2 min!**

<u>ESA's LL-OGS Ground Terminal</u>

- ✓ Received communication D/L to ESA's OGS at 40 Mbps (new station)
- o Fine-tracking on U/L sometimes achieved at LLST, but signal level is still 5 dB too low to permit U/L comm
- o Final week of passes will try to exercise improved OGS U/L beam pointing

JPL's OCTL Facility in Southern CA

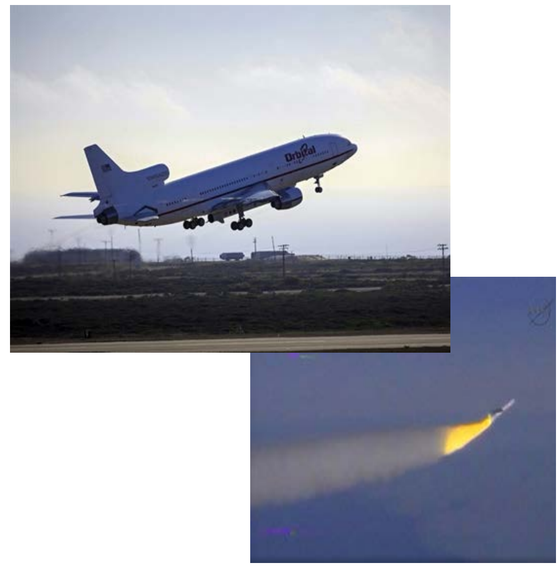
ESA Image of the LLST Beam

ESA's LL-OGS on Tenerife, Spain

Launch Services Program -- CY13 Launch Highlights

January 30, 2013

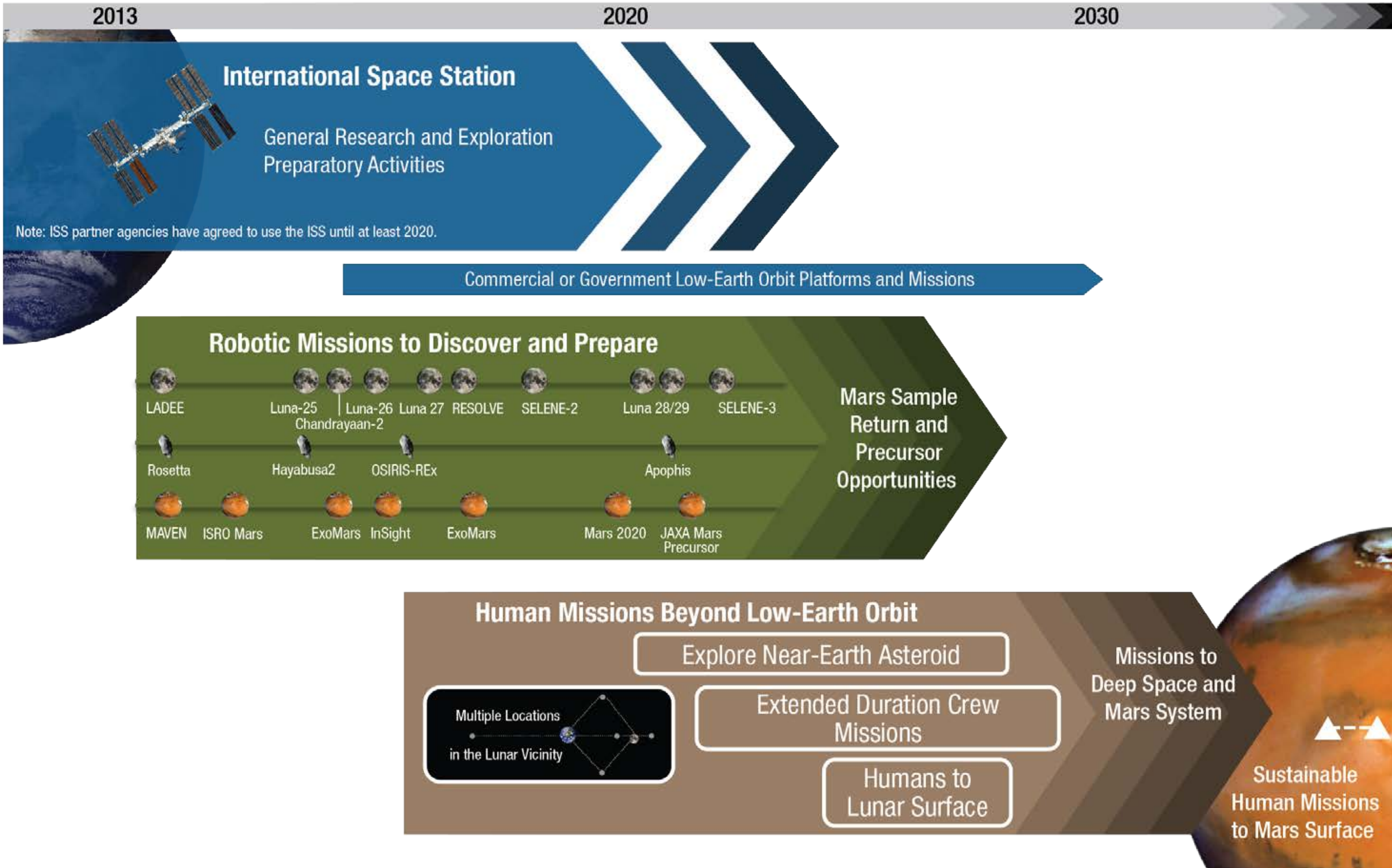
February 11, 2013



June 27, 2013

November 18, 2013

Global Exploration Roadmap



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